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Implementation of Modeling the Land-Surface/Atmosphere Interactions to Mesoscale Model COAMPS

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LONG-TERM GOALS

The long-term goal of this project is to improve the treatment of convection and the prediction of convective precipitation in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®[1]), by including selected land-surface and urban canopy schemes in COAMPS, along with tools that will allow the user to choose the optimum ones for selected nested-grid configurations.

OBJECTIVES

The objectives of this project are to: (a) integrate land-surface models and urban canopy schemes into COAMPS, (b) evaluate the limitations of the proposed schemes in describing surface-atmosphere interactions during drought conditions, (c) investigate the impact of land-atmosphere interactions on Quantitative Precipitation Forecast (QPF) skill, and (d) validate the COAMPS model performance when using the land-surface and urban canopy schemes.

APPROACH

Our approach is to use COAMPS to study the impact of land-vegetation processes on the prediction of mesoscale convection over central Europe during summer months. This will be accomplished by implementing new and more detailed surface databases into COAMPS, developing a new data assimilation system for surface parameters, and performing numerical tests with COAMPS to determine the importance of selected parameters within the land-surface model (LSM). The results of this study will be applicable to similar continental areas.

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[1] COAMPS® is a registered trademark of the Naval Research Laboratory.

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WORK COMPLETED

During FY12, we accomplished the following tasks: (a) performed 14 individual case studies of intense rainfall over Poland using COAMPS with and without the LSM, and performed objective and subjective evaluations of these forecasts; and (b) performed a number of experiments focused on comparisons of parameterized convection with explicit moist physics on grids using horizontal resolutions as low as 1 km.

RESULTS

A series of 14 individual significant precipitation events during 2010 were selected. The initial conditions for these forecasts all began at 0000 UTC on the dates 5, 10, 13, 18, and 20 May; and 3, 6, 9, 12, 13, 15, 16, and 22 August. Two COAMPS forecasts were run for each of these times, one using the current slab model to represent the land-surface conditions (NOLSM) while the other used the NOAH LSM (LSM). Each of these 24 h forecasts were preceded by two 6 h analysis/forecast cycles, designed to allow the model to spin-up mesoscale circulations in the initial conditions prior to the 24 h forecasts, rather than just starting the 24 h forecasts from the global fields that generally lack these mesoscale structures. For the LSM runs, the initial fields for the surface information (e.g., vegetation type, greenness fraction, soil moisture) were derived from fields from the NASA Land Information System (LIS), which were obtained from the Air Force Weather Agency (AFWA).

All the COAMPS forecasts were run using the double-nested grid structure shown in Fig. 1. The coarse and inner meshes used horizontal grid spacing of 9 and 3 km, respectively. Both grids used explicit moist microphysics to represent convection rather than parameterizing the effects of convection. Also, the initial conditions for the first 6 h forecast for each case, and the lateral boundary conditions for all the forecasts were obtained from the NOAA Global Forecast System (GFS) 1/2-degree fields, with a 3 h frequency used for the lateral boundary conditions.

An objective scoring was done for the fields produced by the 14 NOLSM and LSM test cases. Forecast fields from the 9 km grid were evaluated against observations by interpolating the COAMPS forecast fields to the observation points. The results of these evaluations are shown in Table 1. In this table, the mean error and standard deviations are shown for the temperature, wind, height, and dew-point depression for selected output levels. The significance of the differences in the errors between the NOLSM and LSM runs is summarized in the Win/Push/Lose (WPL) column. A value of "+1" for WPL means that the LSM runs are better than those of the NOLSM for that parameter and level at the 95% confidence level. Likewise, a value of "-1" for WPL means that the NOLSM runs are better than those of the LSM for that parameter and level at the 95% confidence level. A value of "0" for WPL means that there is no statistically significant difference between the NOLSM and LSM runs. Table 1 shows that WPL is "0" at all the levels and for all variables. This indicates that at least on the 9 km domain, that there is no statistically significant difference between the NOLSM and LSM runs.

Although the objective scoring over the 9 km grid did not show any statistically significant differences between the NOLSM and LSM runs, some important differences become evident by examining some of the case studies in detail. The results of the NOLSM and LSM forecasts for the test case starting at 0000 UTC 16 August 2010 will be addressed here. Figure 2 shows the 10 m winds at 18 h for these forecasts along with the verifying analysis. A strong frontal system is evident stretching from central Poland to the southern border at this time (and during previous and later hours, not shown). In the NOLSM run, the frontal structure is weaker and further to the west (i.e., slower) than in the verifying analysis. In the LSM run, while the winds are perhaps slightly weaker than observed, they are stronger

than in the NOLSM run, and the position of the front agrees much better than the position of the front in the NOLSM run. Fig. 3 gives the COAMPS-derived radar reflectivity for the NOLSM and LSM runs and the verifying radar reflectivity for the same forecast time (18 h). These fields support the fact that the LSM forecast of the heavy precipitation band associated with the front is much more closely aligned with the observed precipitation band than in the NOLSM forecast. The 21 h forecast 10 m air temperature (Fig. 4) also shows that the front in the LSM run moved faster, and was more aligned with the verifying position of the front than in the NOLSM run. These fields, as well as the fields at other earlier and later times, and for 3 other test cases (not shown), illustrate that the LSM runs were able to simulate the development and movement of significant precipitation events as well as, or better than the NOLSM runs. It is also apparent from Fig. 4 that the low-level temperature in the LSM run are roughly 1 K warmer than those in the NOLSM run, an indication of the elimination of the cold bias in COAMPS by the inclusion of the LSM. This was also seen in the other test cases.

Summary: The NOAH Land-Surface Model has been incorporated in the mesoscale model, COAMPS. Tests have shown, that while there are no statistically significant differences in the overall statistics using the LSM in the selected cases, individual case studies show improvement in the development, movement, and location of some significant precipitation events in Poland. Comparing additionally explicit moist physics results with parameterized convection results on fine meshes (3 and 1 km) we can conclude that explicit moist physics gives in general more precipitation than observed while the parameterized convection produces less precipitation than observed. These findings concern an areal coverage.

PERSONNEL EXCHANGES AND TRAVEL COMPLEMENTED

Bogumil Jakubiak, University of Warsaw – participated in ESA, iLEAPS EGU joint Conference   in Frascati, Italy in a period 3-5 Nov 2010, giving one oral presentation.

Richard Hodur, University of Warsaw, ICM, working for ICM in US – visited ICM, University of Warsaw, during a period 28 Nov- 08 Dec 2010, working on development of the COAMPS system.

Bogumil Jakubiak, University of Warsaw – participated in COST Action ES0905 workshop on “Concepts for Convective parameterization in large-scale models. IV: Convection organization. Cambridge, UK, 23-25 March 2011, giving one oral presentation titled “Some questions about lightning data assimilation into mesoscale models”.

Richard Hodur, University of Warsaw, ICM, working for ICM in US – visited ICM, University of Warsaw, during a period 15 - 26 May 2011, working on development of the COAMPS system.

Bogumil Jakubiak, University of Warsaw – participated in Agriculture Conference in Tlen, Poland, 29 June - 01 July 2011, giving two oral presentations.

Bogumil Jakubiak, University of Warsaw – participated in ITEE Conference in Poznan, Poland, 8 - 8 July 2011, giving one oral presentation.

Karolina Szafranek, University of Warsaw, participated in 11th ESM Annual Meeting and 10th European Conference on Applications of meteorology, Berlin, Germany, 12-16 Sep 2011, taking part in a course and workshop “Tools for forecasting high impact weather”.

Richard Hodur, University of Warsaw, ICM, working for ICM in the US, visited ICM, University of Warsaw, from 27 November-8 December 2011 to work on the development and testing of COAMPS.

Bogumil Jakubiak, University of Warsaw – participated in COST Action ES0905 workshop on "Concepts for Convective parameterization in large-scale models. IV: Convection organization. Cambridge, UK, 23-25 March 2011, giving one oral presentation titled "Some questions about lightning data assimilation into mesoscale models".

Richard Hodur, University of Warsaw, ICM, presented a paper to European Geophysical Society in Vienna, Austria, 25-27 April 2012, titled: "Impact of a Land Surface Model (LSM) in a Mesoscale Model on the Prediction of Heavy Precipitation Events".

Richard Hodur, University of Warsaw, ICM, presented a paper to the European Meteorological Society in Lodz, Poland, 10-13 September 2012, titled "The Role of Surface Forcing on Significant Precipitation Events in a Mesoscale Model" and visited ICM, University of Warsaw, from 14-19 September 2012 to continue work on COAMPS.

IMPACT/APPLICATIONS

This improvement in the treatment of surface conditions in COAMPS will be useful for improving forecasts of the boundary layer structure and precipitation.

TRANSITIONS

None.

RELATED PROJECTS

COST Action 731 project – Propagation of uncertainty in advanced meteo-hydrological forecast systems. Within this action, we started to develop a radar data assimilation scheme using the ensemble Kalman filter approach.

COST ESSEM Action ES0905 – Basic Concepts for Convection Parameterization in Weather Forecast and Climate Models

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Table 1. Objective scoring for the NOLSM and LSM 24 h forecasts for all 14 case studies. Scoring is displayed for the wind, temperature, dew-point depression, and height at different levels. WPL stands for Win/Push/Loss and can be either "+1", "0", or "-1", with "+1" indicating that the LSM forecasts were better than the NOLSM forecasts with a confidence level of 95%, "-1" indicating that the NOLSM forecasts were better than the LSM forecasts with a confidence level of 95%, and "0" indicating that there is no statistical difference between the NOLSM and LSM runs.

Obs	Level	Parameter	Error-Type	WPL	Err NOLSM	Err LSM
Raob	250 mb	Wind (m/s)	Vector RMS	0	6.89	6.95
Raob	250 mb	Height (m)	STD DEV	0	13.92	13.66
Raob	250 mb	Height (m)	Mean Error	0	-0.99	3.52
Raob	250 mb	Temp (C)	STD DEV	0	1.32	1.25
Raob	250 mb	Temp (C)	Mean Error	0	0.99	0.95
Raob	500 mb	Height (m)	STD DEV	0	7.44	7.45
Raob	500 mb	Height (m)	Mean Error	0	-5.22	-2.73
Raob	500 mb	Temp (C)	STD DEV	0	0.80	0.82
Raob	500 mb	Temp (C)	Mean Error	0	-0.06	0.08
Raob	500 mb	T_d (C)	STD DEV	0	5.46	5.78
Raob	500 mb	T_d (C)	Mean Error	0	-0.27	-0.46
Raob	850 mb	Wind (m/s)	Vector RMS	0	4.32	4.42
Raob	850 mb	Height (m)	STD DEV	0	5.75	6.04
Raob	850 mb	Height (m)	Mean Error	0	-3.37	-2.42
Raob	850 mb	Temp (C)	STD DEV	0	1.20	1.27
Raob	850 mb	Temp (C)	Mean Error	0	-0.29	-0.19
Raob	850 mb	T_d (C)	STD DEV	0	2.09	2.15
Raob	850 mb	T_d (C)	Mean Error	0	-0.12	0.17
Sfc	10 m	Wind (m/s)	Vector RMS	0	2.65	2.65
Sfc	2 m	Temp (C)	STD DEV	0	1.65	1.75
Sfc	2 m	Temp (C)	Mean Error	0	-0.19	0.42
Sfc	2 m	T_d (C)	STD DEV	0	1.57	1.82
Sfc	2 m	T_d (C)	Mean Error	0	0.05	0.19

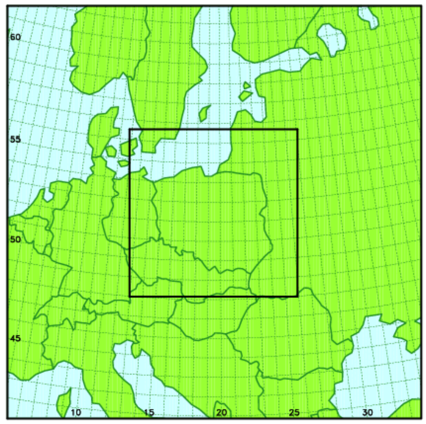

Figure 1. Double-nested grids used for all experiments. The outer grid uses a 9 km grid spacing while the inner grid uses a 3 km resolution. The grids use a Lambert Conformal projection.

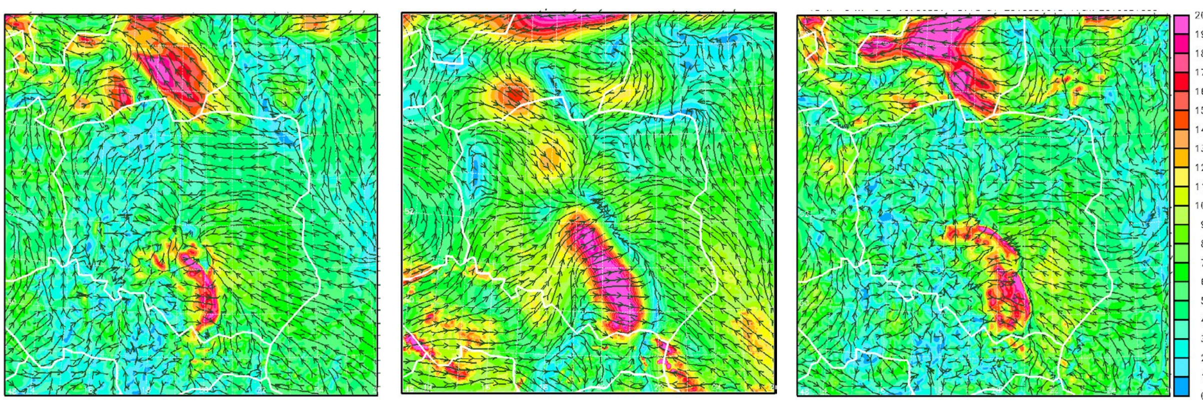

Figure 2. The 18 h forecast of the 10 m winds for the NOLSM run on the 3 km grid (left), the 10 m verifying wind analysis (center), and the 18 h forecast of the 10 m winds for LSM on the 3 km grid (right). All fields are valid at 1800 UTC 16 August 2010. The wind speeds are given in knots.

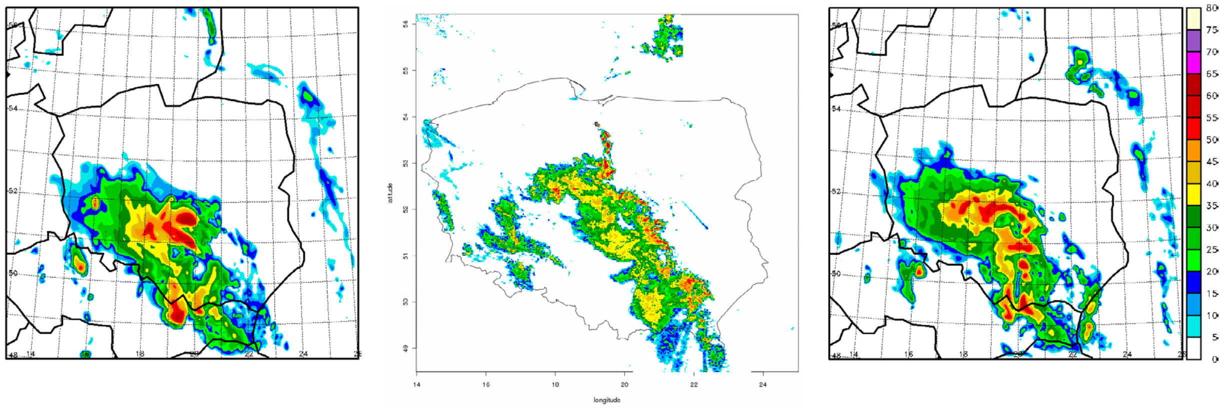

Figure 3. The 18 h model-derived radar reflectivity for the NOLSM run on the 3 km grid (left), the observed radar reflectivity (center), and the 18 h model-derived radar reflectivity for the LSM run on the 3 km grid (right). All fields are valid at 1800 UTC 16 August 2010. The radar reflectivity is given in dBz. The radar reflectivity values from the NOLSM and LSM cases are the maximum radar reflectivity at each grid point.

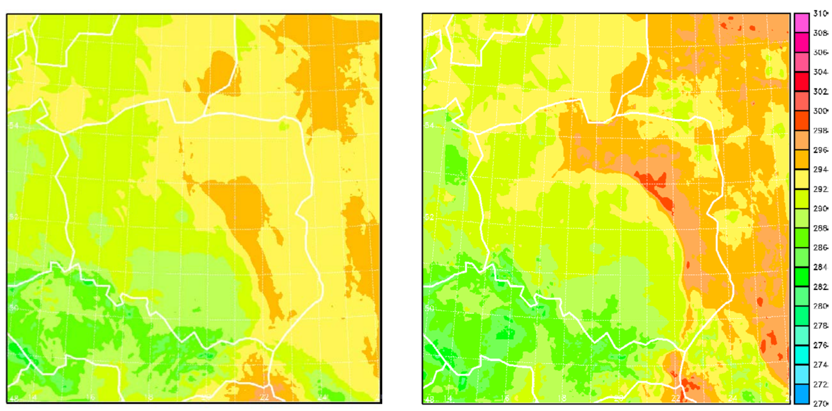

Figure 4. The 21 h forecast of the 1000 mb temperature for the NOLSM run (left)) and for the LSM run (right), on the 3 km grid. All fields are valid at 2100 UTC 16 August 2010. The temperatures are given in K.